

Appl. No. 10/024,167

Amendment Dated March 31, 2004

Reply to Office Action of January 6, 2004

**Amendments to the Claims:**

This listing of claims will replace all prior versions and listings of claims in the application:

**Listing of Claims:**

1-10. (Canceled)

11. (Currently amended) A waste gas desulfurization process comprising:providing a H<sub>2</sub>S-containing waste gas stream;providing a O<sub>2</sub>-containing stream;in a millisecond contact time reactor having a gas mixing zone, a reaction zone, and a cooling zone, mixing together said H<sub>2</sub>S-containing gas stream and said O<sub>2</sub>-containing gas stream in said mixing zone to form a reactant gas mixture, said reaction zone containing a catalyst device having activity for catalyzing the partial oxidation of H<sub>2</sub>S to elemental sulfur and water;maintaining the temperature of said reaction zone above 300°C;passing said reactant gas mixture over said catalyst device such that the contact time between said catalyst device and a portion of said reactant gas mixture that contacts said catalyst device is sufficiently brief to allow the reaction  $H_2S + 1/2 O_2 \rightarrow 1/x S_x + H_2O$  (x = 2, 6 or 8) to occur, and a product gas stream is formed comprising gaseous elemental sulfur and water;passing said product gas stream into said cooling zone and cooling said product stream to a temperature above the dewpoint of sulfur, to provide a partially cooled product stream;passing said partially cooled product stream into a sulfur condenser and further cooling said partially cooled product stream to the dewpoint temperature of elemental sulfur, or lower. ~~The process of claim 10~~ wherein at least the reaction zone of said reactor is capable of withstanding temperatures of at least 1,500°C, said H<sub>2</sub>S-containing gas stream and said O<sub>2</sub>-containing gas stream are combined in said mixing zone to form a reactant gas mixture having a molar ratio of H<sub>2</sub>S to O<sub>2</sub> of about 2:1 or less, and the temperature of said reaction zone is 700-1,500°C.12. (Currently amended) The process of claim [10] 13 comprising preheating said H<sub>2</sub>S and/or O<sub>2</sub> stream up to about 200°C before contacting said catalyst device.

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13. (Previously presented) A waste gas desulfurization process comprising:  
providing a  $\text{H}_2\text{S}$ -containing waste gas stream;  
providing a  $\text{O}_2$ -containing stream;  
in a millisecond contact time reactor having a gas mixing zone, a reaction zone, and a cooling zone, mixing together said  $\text{H}_2\text{S}$ -containing gas stream and said  $\text{O}_2$ -containing gas stream in said mixing zone to form a reactant gas mixture, said reaction zone containing a catalyst device having activity for catalyzing the partial oxidation of  $\text{H}_2\text{S}$  to elemental sulfur and water;  
maintaining the temperature of said reaction zone above  $300^\circ\text{C}$ ;  
passing said reactant gas mixture over said catalyst device such that the contact time between said catalyst device and a portion of said reactant gas mixture that contacts said catalyst device is sufficiently brief to allow the reaction  $\text{H}_2\text{S} + 1/2 \text{O}_2 \rightarrow 1/x \text{S}_x + \text{H}_2\text{O}$  ( $x = 2, 6$  or  $8$ ) to occur, and a product gas stream is formed comprising gaseous elemental sulfur and water;  
passing said product gas stream into said cooling zone and cooling said product stream to a temperature above the dewpoint of sulfur, to provide a partially cooled product stream;  
passing said partially cooled product stream into a sulfur condenser and further cooling said partially cooled product stream to the dewpoint temperature of elemental sulfur, or lower, wherein said contact time is no more than about 200 milliseconds.
14. (Currently amended) The process of claim [10] 13 comprising recovering a product comprising elemental sulfur and, optionally, venting a substantially desulfurized residual gas.
15. (Currently amended) The process of claim [10] 13 comprising providing a  $\text{H}_2\text{S}$ -containing gas containing at least about 1 vol.%  $\text{H}_2\text{S}$ .
16. (Currently amended) The process of claim [10] 13 wherein said  $\text{O}_2$ -containing gas is chosen from the group consisting of purified  $\text{O}_2$ , air, and  $\text{O}_2$  enriched air.
17. (Currently amended) A waste gas desulfurization process comprising:  
providing a  $\text{H}_2\text{S}$ -containing waste gas stream;  
providing a  $\text{O}_2$ -containing stream;

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in a millisecond contact time reactor having a gas mixing zone, a reaction zone, and a cooling zone, mixing together said H<sub>2</sub>S-containing gas stream and said O<sub>2</sub>-containing gas stream in said mixing zone to form a reactant gas mixture, said reaction zone containing a catalyst device having activity for catalyzing the partial oxidation of H<sub>2</sub>S to elemental sulfur and water;

maintaining the temperature of said reaction zone between about 850°C - 1,300°C;

passing said reactant gas mixture over said catalyst device such that the contact time between said catalyst device and a portion of said reactant gas mixture that contacts said catalyst device is sufficiently brief to allow the reaction  $H_2S + 1/2 O_2 \rightarrow 1/x S_x + H_2O$  ( $x = 2, 6$  or  $8$ ) to occur, and a product gas stream is formed comprising gaseous elemental sulfur and water;

passing said product gas stream into said cooling zone and cooling said product stream to a temperature above the dewpoint of sulfur, to provide a partially cooled product stream;

passing said partially cooled product stream into a sulfur condenser and further cooling said partially cooled product stream to the dewpoint temperature of elemental sulfur, or lower.  
~~The process of claim 10 further comprising maintaining the temperature of said reaction zone between about 850°C - 1,300°C.~~

18. (Original) The process of claim 17 further comprising regulating reactor inlet temperatures, regulating H<sub>2</sub>S concentration in the reactant gas mixture, and/or applying heat to said catalyst device such that the temperature of said catalyst device is maintained at a desired temperature between said 850-1,300°C.

19. (Original) The process of claim 17 further comprising maintaining autothermal reaction promoting conditions.

20. (Currently amended) The process of claim [10] 13 wherein said catalyst device comprises at least one metal chosen from the group consisting of platinum, rhodium, ruthenium, iridium, nickel, palladium, iron, cobalt, rhenium, rubidium, vanadium, bismuth and antimony.

21. (Original) The process of claim 20 wherein said catalyst device comprises at least one metal chosen from the group consisting of platinum, rhodium, ruthenium, iridium, nickel, palladium, iron, cobalt, rhenium and rubidium.

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22. (Original) The process of claim 21 wherein said catalyst device comprises at least one metal chosen from the group consisting of platinum, rhodium, ruthenium, nickel, palladium and iridium

23. (Original) The process of claim 22 wherein said catalyst device comprises platinum, rhodium or a mixture thereof.

24. (Original) The process of claim 20 wherein said catalyst device comprises vanadium, bismuth or antimony.

25. (Previously presented) The process of claim 20 wherein said catalyst device comprises at least one lanthanide element (Ln) chosen from the group consisting of La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu.

26. (Original) The process of claim 25 wherein at least one said lanthanide element is samarium, ytterbium or praseodymium.

27. (Currently amended) The process of claim [10] 13 wherein said catalyst device comprises at least one structure chosen from the group consisting of gauzes, monoliths and a plurality of divided units.

28. (Previously presented) The process of claim 27 wherein said divided units are selected from the group consisting of particles, granules, beads, pills, pellets, cylinders, trilobes, extrudates or spheres.

29. (Original) The process of claim 27 wherein said structure comprises a refractory support.

30. (Original) The process of claim 29 wherein said catalyst refractory support comprises zirconia or alumina.

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31. (Currently amended) The process of claim [10] 13 wherein said catalyst device comprises platinum and a lanthanide metal oxide chosen from the group consisting of cerium oxide and lanthanum oxide.

32. (Original) The process of claim 31 wherein said catalyst device comprises rhodium and samarium oxide.

33. (Currently amended) A waste gas desulfurization process comprising:  
providing a H<sub>2</sub>S-containing waste gas stream;  
providing a O<sub>2</sub>-containing stream;  
in a millisecond contact time reactor having a gas mixing zone, a reaction zone, and a cooling zone, mixing together said H<sub>2</sub>S-containing gas stream and said O<sub>2</sub>-containing gas stream in said mixing zone to form a reactant gas mixture, said reaction zone containing a catalyst device having activity for catalyzing the partial oxidation of H<sub>2</sub>S to elemental sulfur and water;  
maintaining the temperature of said reaction zone above 300°C;  
passing said reactant gas mixture over said catalyst device such that the contact time between said catalyst device and a portion of said reactant gas mixture that contacts said catalyst device is sufficiently brief to allow the reaction  $H_2S + 1/2 O_2 \rightarrow 1/x S_x + H_2O$  (x = 2, 6 or 8) to occur, and a product gas stream is formed comprising gaseous elemental sulfur and water;  
passing said product gas stream into said cooling zone and cooling said product stream to a temperature above the dewpoint of sulfur, to provide a partially cooled product stream;  
passing said partially cooled product stream into a sulfur condenser and further cooling said partially cooled product stream to the dewpoint temperature of elemental sulfur, or lower.  
~~The process of claim 10~~ wherein said catalyst device comprises a platinum-rhodium alloy disposed on a lanthanide oxide coated refractory support.

34. (Original) The process of claim 33 wherein said catalyst device comprises a samarium oxide coated refractory support.

35. (Currently amended) A waste gas desulfurization process comprising:

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providing a  $H_2S$ -containing waste gas stream;

providing a  $O_2$ -containing stream;

in a millisecond contact time reactor having a gas mixing zone, a reaction zone, and a cooling zone, mixing together said  $H_2S$ -containing gas stream and said  $O_2$ -containing gas stream in said mixing zone to form a reactant gas mixture, said reaction zone containing a catalyst device having activity for catalyzing the partial oxidation of  $H_2S$  to elemental sulfur and water;

maintaining the temperature of said reaction zone above  $300^\circ C$ ;

passing said reactant gas mixture over said catalyst device such that the contact time between said catalyst device and a portion of said reactant gas mixture that contacts said catalyst device is sufficiently brief to allow the reaction  $H_2S + 1/2 O_2 \rightarrow 1/x S_x + H_2O$  ( $x = 2, 6$  or  $8$ ) to occur, and a product gas stream is formed comprising gaseous elemental sulfur and water;

passing said product gas stream into said cooling zone and cooling said product stream to a temperature above the dewpoint of sulfur, to provide a partially cooled product stream;

passing said partially cooled product stream into a sulfur condenser and further cooling said partially cooled product stream to the dewpoint temperature of elemental sulfur, or lower. The process of claim 10 wherein said catalyst device comprises at least one catalytic carbided metal.

36. (Original) The process of claim 35 wherein said carbided metal comprises platinum and rhodium.

37. (Currently amended) The process of claim [10] 13 comprising operating said reactor at a space velocity of at least about  $20,000 \text{ hr}^{-1}$ .

38. (Currently amended) The process of claim [10] 13 comprising operating said reactor at superatmospheric pressure.

39-53. (Canceled)

54. (Currently amended) A waste gas desulfurization process comprising:

a) providing a  $H_2S$ -containing waste gas stream;



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b) providing a O<sub>2</sub>-containing stream;

c) in a millisecond contact time reactor having a gas mixing zone, a reaction zone, and a cooling zone, mixing together said H<sub>2</sub>S-containing gas stream and said O<sub>2</sub>-containing gas stream in said mixing zone to form a reactant gas mixture, said reaction zone containing a catalyst device having activity for catalyzing the partial oxidation of H<sub>2</sub>S to elemental sulfur and water;

d) maintaining the temperature of said reaction zone above 300°C;

e) passing said reactant gas mixture over said catalyst device such that the contact time between said catalyst device and a portion of said reactant gas mixture that contacts said catalyst device is sufficiently brief to allow the reaction  $H_2S + 1/2 O_2 \rightarrow 1/x S_x + H_2O$  (x = 2, 6 or 8) to occur, and a product gas stream is formed comprising gaseous elemental sulfur and water;

f) prior to step e), in said reactor, passing a gaseous hydrocarbon over said catalyst device to carbide said catalyst device, and subsequently beginning flow of said H<sub>2</sub>S containing reactant gas mixture over said carbided catalyst device at a temperature sufficient to initiate H<sub>2</sub>S catalytic partial oxidation to form elemental sulfur and water;

g) passing said product gas stream into said cooling zone and cooling said product stream to a temperature above the dewpoint of sulfur, to provide a partially cooled product stream;

h) passing said partially cooled product stream into a sulfur condenser and further cooling said partially cooled product stream to the dewpoint temperature of elemental sulfur, or lower. The process of claim 10 comprising, in said reactor, passing a gaseous hydrocarbon over said catalyst device to carbide said catalyst device, and subsequently beginning flow of said H<sub>2</sub>S containing gas over said carbided catalyst device at a temperature sufficient to initiate H<sub>2</sub>S catalytic partial oxidation to form elemental sulfur and water.

55. (Currently amended) The process of claim [10] 13 wherein said contact time is less than 50 milliseconds.

56. (Currently amended) The process of claim [10] 13 wherein said contact time is less than 20 milliseconds.

57. (Currently amended) A waste gas desulfurization process comprising:  
providing a H<sub>2</sub>S-containing waste gas stream;

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providing a O<sub>2</sub>-containing stream;

in a millisecond contact time reactor having a gas mixing zone, a reaction zone, and a cooling zone, mixing together said H<sub>2</sub>S-containing gas stream and said O<sub>2</sub>-containing gas stream in said mixing zone to form a reactant gas mixture, said reaction zone containing a catalyst device having activity for catalyzing the partial oxidation of H<sub>2</sub>S to elemental sulfur and water;

maintaining the temperature of said reaction zone above 300°C;

passing said reactant gas mixture over said catalyst device such that the contact time between said catalyst device and a portion of said reactant gas mixture that contacts said catalyst device is sufficiently brief to allow the reaction  $H_2S + 1/2 O_2 \rightarrow 1/x S_x + H_2O$  ( $x = 2, 6$  or  $8$ ) to occur, and a product gas stream is formed comprising gaseous elemental sulfur and water;

passing said product gas stream into said cooling zone and cooling said product stream to a temperature above the dewpoint of sulfur, to provide a partially cooled product stream;

passing said partially cooled product stream into a sulfur condenser and further cooling said partially cooled product stream to the dewpoint temperature of elemental sulfur, or lower. The process of claim 10 wherein said contact time is less than 10 milliseconds.

58. (Previously presented) The process of claim 35 wherein H<sub>2</sub>S conversion is at least about 82%, selectivity for elemental sulfur product is at least about 70% and selectivity for SO<sub>2</sub> is no more than about 10-13%.